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EVALUATION OF FIKE[®] CORPORATION'S EXPLOSION SUPPRESSION SYSTEM FOR ULTRA-HIGH SPEED FIRE SUPPRESSION APPLICATIONS

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Evaluation of Fike[®] Corporation's Explosion Suppression System for Ultra-High Speed Fire Suppression Applications

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Abstract

The Air Force Research Laboratory Fire Research Group at Tyndall Air Force Base has a long history of researching ultra high-speed fire extinguishing systems for suppressing fires at munitions facilities. This report documents results of evaluation of Fike[®] Corporation's ultra-high speed explosion protection system when presented with fires from fast burning propellant and pyrotechnic materials. A total of nine tests were conducted using M6 propellant and M206 magnesium-Teflon[®] pyrotechnic material in amounts ranging from ¼ lb to 2 lbs. Reaction times were determined using a data acquisition system in conjunction with a high-speed digital camera. The reaction time of Fike[®] Corporation's system, controller and high rate discharge container, ranged from 2.1–2.9 ms, with an average of 2.5 ms.

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1 Summary

The Air Force Research Laboratory (AFRL) Fire Research Group at Tyndall Air Force Base has endeavored to develop an ultra high-speed fire extinguishing system for suppressing fires at munitions facilities. The Advanced Fire Protection Deluge System (AFPDS) developed by AFRL had a response time of 6–8 ms, including the detector response time, far superior to the 100 ms response time requirement set by National Fire Protection Association (NFPA) Standard 15¹. The reaction time for the AFPDS controller and high rate discharge container, not including detector reaction time, is just 2–3 ms. AFPDS has been installed at a number of installations, however, two drawbacks to AFPDS are that no single manufacturer makes all the key components of the system, and no commercial fire protection equipment installer can procure, install, and warranty the system. In an effort to offer facilities owners a commercial alternative to AFPDS, the Fire Research Group evaluated Fike[®] Corporation's ultra-high speed explosion protection system, coupled with a multi-spectrum detector, as a possible alternative to the AFPDS.

Three sizes of high rate discharge (HRD) containers were evaluated: 2.6 gal (10 L), 7.9 gal (30 L), and 13.2 gal (50 L). A Fike power supply and a Fike explosion protection controller were also used. Assessments were done using a multi-spectrum, ultraviolet (UV) and infrared (IR), Fire Sentry[™] SS2-AM ultra-high speed flame detector.

A total of nine laboratory trials were conducted using M6 propellant and M206 magnesium-Teflon[®] (MTV) pyrotechnic material in amounts ranging from ¼ lb to 2 lbs. Samples were burned on a table top 32 in below the nozzles of the HRD containers. Reaction times were determined by using a data acquisition system in conjunction with a high-speed digital camera.

The combined reaction time of the controller and the HRD containers ranged from 2.1–2.9 ms with an average reaction time of 2.5 ms, compared to a reaction time of 2–3 ms for the AFPDS controller and HRD container. The average time to extinguish ¼ lb of M6 propellant was 13 ms, measured from the time that water first exited the nozzle until the flame was extinguished. The average time to extinguish 2 lbs of MTV with the 50L container was 28 ms.

The results of these evaluations demonstrate that Fike Corporation's explosion suppression system is capable of suppressing propellants and fast burning pyrotechnic materials.

2 Introduction

Since 1994, the AFRL Fire Research Group at Tyndall Air Force Base has progressively developed higher speed, more effective fire suppression systems aimed at extinguishing fast advancing fires caused by deflagration of explosives, propellants, and pyrotechnic materials.^{2,3,4} NFPA 15 defines ultra-high speed fire protection systems as those with response times of 100 ms or less. AFRL's AFPDS achieved a total system

response time (defined in National Fire Protection Association [NFPA] Standard 15 to be the time from presentation of an energy source of sufficient intensity to initiate detection until extinguishing agent leaves the extinguisher nozzle) of 6–8 ms, and a reaction time for the controller and HRD alone of 2–3 ms. The AFPDS has been installed at six munitions facilities and one paint manufacturing plant. Individual components of the AFPDS, primarily the extinguisher container and the system controller, have come from different manufacturers in an effort to minimize system response time, and up to the present no single commercial manufacturer of fire suppression equipment has expressed interest in transitioning the AFPDS to commercial production.

In 2006, the AFRL Fire Research Group evaluated Fike® Corporation's ultra-high speed explosion protection system as a possible alternative to the AFPDS. Fike® manufactures all of the components that were used to assemble the test system except for the optical detectors.

The reaction time of Fike's system was evaluated in this study. Nine trials were conducted using Fike® explosion suppression containers, power supply units, and explosion protection controllers. Optical detectors used in these trials were the same multi-spectrum detectors typically installed with the AFPDS. M6 propellant and M206 MTV pyrotechnic material were used as the fire sources.

3 Methods, Assumptions, and Procedures

Five major components make up Fike's HRD containers (Figure 1): the steel vessel, a rupture disk, a dispersion nozzle, a nitrogen fill valve, and a gas cartridge actuator (GCA). The steel vessel is available in seven different volumes. For these experiments, 2.6 gal (10 L), 7.9 gal (30 L), and 13.2 gal (50 L) vessels were used. The containers were filled with 15 lbs, 45 lbs, and 80 lbs of water, respectively, and pressurized to 900 ± 25 psi with nitrogen. The rupture disk is non-

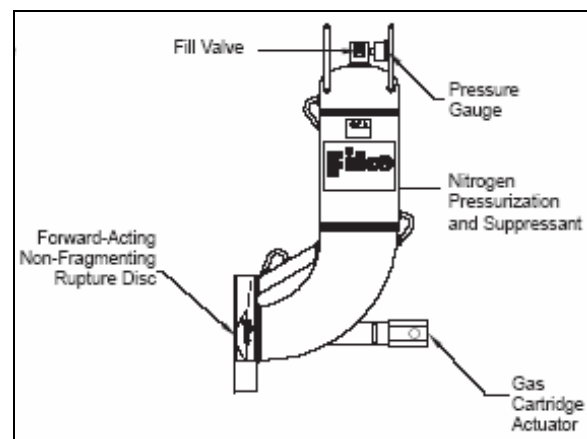


Figure 1. Fike High Rate Discharge Container

fragmenting and held in place by a hold down ring. The dispersion nozzle (Figure 2) bolts to the end of the vessel. The hole pattern in the dispersion nozzle yields a spray coverage angle of about 150°. The 10 L and 30 L HRD use 4 in dispersion nozzles, and the 50 L HRD uses a 6 in dispersion

nozzle. The GCA is a thermo-chemical device that is mounted in the HRD in such a manner that it acts directly on the rupture disk when initiated by electrical signal from the system controller. The GCA is classified as a special explosive device by the U.S. Bureau of Alcohol, Tobacco, and Firearms and is exempt from the licensing and storage requirements contained in the Federal explosives regulations. Reference 5 gives additional information about the Fike[®] explosion suppression system.

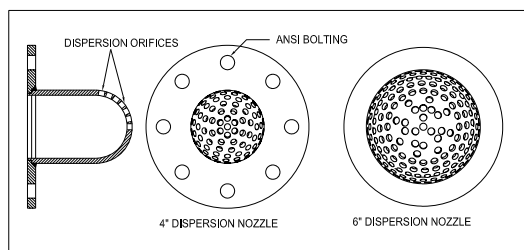


Figure 2. Fike Dispersion Nozzle

A multi-spectrum, ultraviolet (UV) and infrared (IR), Fire Sentry[™] SS2-AM ultra-high speed flame detector was used in seven of the nine experiments conducted. This type of detector was chosen because it has been used in previous studies of the AFPDS and was, therefore, the best choice for making direct comparisons between the two ultra-high speed suppression systems. An experimental detector invented here at AFRL was used in the other two experiments, but because of the design of the experimental detector a detection signal could not be measured by the data acquisition system, and therefore a controller reaction time could not be determined for two of the nine trials.

A Hi-Techniques meDAQ data acquisition system was used in conjunction with a Vision Research Phantom v4.2 high-speed digital camera to determine the reaction time of the suppression system. The camera was set outside the blast door entrance to the test room, aimed toward the test table through the polycarbonate window in the door. The meDAQ and the high-speed camera were triggered simultaneously when the device used to ignite the combustible material was activated. Signals to the meDAQ recorded the time when the flame detector sent a signal to the controller and when the controller sent an activation signal to the GCA. The time difference between these two signals is the controller reaction time. The time when water first left the nozzle of the HRD was determined by observing high-speed camera images. Since the data acquisition system and the camera were triggered simultaneously, the reaction time of the HRD, the time from an activation signal at the GCA until water was observed exiting the HRD nozzle, could be determined. The meDAQ was set to a sample rate of 1000 kHz, and the camera shutter speed was set to either 1000 or 2000 frames per second and an exposure time of 300 μ s.

M6 propellant and M206 MTV pyrotechnic material were used as the fire sources. The M6 was ignited by a nichrome bridgewire, and the M206 was ignited by electric match. One-quarter pound amounts were used in trials for the 10 L and 30 L containers. One-half pound and two pound amounts were used in the trials for the 50 L containers.

Figures 3 and 4 show the arrangement of the equipment. The Fike[®] containers were bolted to a mounting bracket that held them in place over the center of the table. The

mounting bracket itself was attached to one of the concrete walls in the test structure. The distance from the nozzle to the table surface was 32 in. A chain hoist mounted to the ceiling of the test structure was used to lift filled containers into place. The flame detector was mounted to a bracket about level with the nozzle and aimed at the center of the tabletop. The square tabletop was 3 ft on a side and made of steel plate.



Figure 3. Test Equipment Arrangement



Figure 4. Container Mounting

The system controller, power supply, and associated equipment (Figure 5) were located in an adjacent room separated from the test room by reinforced concrete walls and a blast resistant door. Cables from the flame detectors to the controller and from the controller to the gas cartridge actuator were run through the walls.

The first step for each trial was to fill the explosion suppression container with the specified amount of water and install the burst disk, nozzle, and GCA.

The container was lifted into place and bolted to the mounting bracket. Once bolted in place, the container was pressurized with nitrogen, and then the activation cables were attached to the CGA. All non-essential personnel left the room before the explosive ordnance disposal (EOD) technician entered with the sample material. The EOD technician mounded the material in the center of the table, inserted the igniter, and attached the power supply leads to the igniter. Once the sample material was in place,



Figure 5. Control Equipment

the EOD technician exited the test room and shut the blast door. The high-speed camera was set in place outside the blast door, and the camera and data acquisition system were set to trigger when the switch was closed to apply voltage to the igniter. When all preparations were complete, the explosion suppression control system was energized and placed in automatic. Trials were initiated by applying a voltage to energize the bridge wire igniter or the electric match. After each trial, data from the meDAQ and images from the high-speed camera were saved, an EOD technician gathered up any remaining sample material in the test room, and then the container was unbolted and lowered so it could be serviced.

The data acquisition system was set to sample at a rate of one sample every microsecond (1000 kHz). The high-speed camera was set to capture 1000 frames per second for some trials and 2000 frames per second for others. At these sampling and capture rates, the error due to measurement tolerances from high-speed camera images was about three orders of magnitude greater than that from the data acquisition system. Therefore, any errors introduced by the meDAQ were insignificant compared to those from high-speed digital images. The exposure time at both camera frame-speed settings was 300 μs . These settings were optimum for available light. When set to 1000 frames per second, the high-speed camera captured one frame every millisecond but only the first 300 μs was captured in each frame; the remaining 700 μs was essentially blank time. At 2000 frames per second, each frame consisted of 300 μs of capture time followed by 200 μs of blank time. This means that at 1000 frames per second it is possible that the time measured for an event could be as much as 1.7 ms later than the actual time the event occurred (Figure 6). At 2000 frames per second, the measured time could be up to 700 μs later than the actual event time. Therefore, the times measured from an activation signal reaching the GCA until water was observed exiting the HRD nozzle (container reaction time) represent an upper bound of the actual container reaction time.

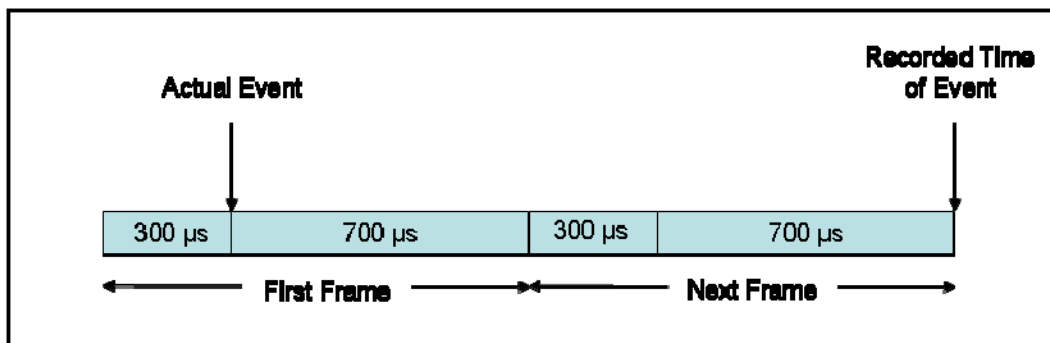


Figure 6. Maximum Error in Measured Reaction Time at 1000 Frames per Second

4 Results and Discussion

Table 1 is a summary of the results of the nine trials.

Table 1. Test Results

CONTAINER VOLUME (L)	DETECTOR	SAMPLE MATERIAL	CAMERA FRAME SPEED (frames/sec)	CONTROLLER REACTION TIME (ms)	CONTAINER REACTION TIME (ms)*	SPEED OF WATER SPRAY (feet/sec)
10	Fire Sentry	¼ lb M6	1000	0.778	2.1	267
10	Fire Sentry	¼ lb M6	1000	1.21	1.3	222
10	AFRL	¼ lb MTV	2000	**	1.5	242
30	Fire Sentry	¼ lb M6	1000	0.945	2.0	242
30	Fire Sentry	¼ lb M6	1000	1.11	1.7	213
30	Fire Sentry	¼ lb MTV	1000	0.758	1.3	222
50	Fire Sentry	½ lb MTV	2000	0.564	1.6	191
50	AFRL	2 lb MTV	2000	**	1.6	185
50	Fire Sentry	2 lb MTV	2000	1.23	***	***
			AVERAGE	0.942	1.6	
			STANDARD DEVIATION	0.254	0.3	
			MEDIAN	0.945	1.6	
* Time is an upper bound to the actual reaction time. For an explanation, see section 3 above.						
** Controller reaction time could not be determined when the AFRL detector was used.						
*** Could not determine time water began to exit the container from high-speed imagery.						

The total reaction time (controller reaction time plus container reaction time) of Fike[®] Corporation's explosion suppression system ranged from 2.1–2.9 ms with an average reaction time of 2.5 ms. The AFPDS controller and HRD have a reaction time of 2–3 ms. The speed of the water spray from the Fike[®] 10 L container averaged 244 ft/s. The speed of the water spray from a 10 L AFPDS container is about 166 ft/s at a container pressure of 500 psi.

Table 2 shows the total time for extinguishing each of the fires. Total time to extinguishment is the time from water first exiting the nozzle until the fire was extinguished. Times were measured from the high-speed digital video records. The average extinguishment time for ¼ lb of M6 propellant was 13 ms, independent of container volume. For MTV, the extinguishment time decreased with increasing container volume, and the average time to extinguish 2 lbs of MTV with the 50L containers was 28 ms.

Table 2. Extinguishment Times

SAMPLE MATERIAL	CONTAINER VOLUME (L)	TOTAL TIME TO EXINGUISHMENT (ms)
¼ lb M6	10	12
¼ lb M6	10	15
¼ lb M6	30	13
¼ lb M6	30	12.5
¼ lb MTV	10	77
¼ lb MTV	30	27
½ lb MTV	50	18
2 lb MTV	50	22
2 lb MTV	50	34.5

5 Conclusions

Fike's system released extinguishing agent within 2–3 ms of detection and extinguished up to 2 lbs of MTV pyrotechnic material in less than 35 ms. System performance was as good as that of the Advanced Fire Protection Deluge System, developed and installed by AFRL, and it is an order of magnitude faster than the standard set by NFPA 15 for ultra-high speed fire protection systems. Unlike the Advanced Fire Protection Deluge System, all components of Fike's system (except for the flame detectors) are commercially available from a single manufacturer. Designers of future energetic materials facilities and caretakers of existing facilities should use this information to determine whether Fike[®] Corporation's ultra-high speed explosion protection system could reduce the potential for human injuries, property damage, and process interruptions at their installations.

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